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Cost-Effectiveness of Telehealth for Chronic Cardiovascular Conditions and Chronic Obstructive Pulmonary Disease in the United States

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ABSTRACT

COST-EFFECTIVENESS OF TELEHEALTH FOR CHRONIC CARDIOVASCULAR CONDITIONS AND CHRONIC OBSTRUCTIVE PULMONARY DISEASE IN THE UNITED STATES

By

TRISHNA KINI

May 29, 2019

INTRODUCTION: The United States has seen a dramatic increase in the incidence of chronic disease, including chronic obstructive pulmonary disease (COPD) and chronic cardiovascular diseases. Telehealth interventions can potentially improve healthcare access and health outcomes in the United States while saving time and economic resources. Conclusive research is needed to show whether telehealth interventions are cost-effective for people living with chronic disease.

AIM: This paper synthesizes the existing literature on the cost-effectiveness of telehealth interventions for patients with chronic cardiovascular conditions (congestive heart failure (CHF), myocardial infarctions, and coronary heart disease) and chronic obstructive pulmonary disease (COPD).

METHODS: A literature search was undertaken to identify studies that assessed the cost-effectiveness of telehealth interventions for chronic cardiovascular diseases and chronic obstructive pulmonary disease (COPD) using PubMed and Scopus.

RESULTS: A thorough literature search using PubMed and Scopus identified 753 articles that fit the search criteria. Of these, 27 articles met inclusion criteria, including 9 literature reviews and 1 meta-analysis. Over 80% of the relevant research was conducted in Europe, Taiwan, and Australia. The combination of a lack of cost-effectiveness research conducted in the United States, methodological challenges in the existing studies, and continued technological advancements, make it clear that further research is needed to make reliable inferences and conclusions.

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by

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APPROVAL PAGE

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Author's Statement Page

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I. Introduction

The United States has seen a dramatic increase in the incidence of chronic disease, including chronic obstructive pulmonary disease (COPD) and chronic cardiovascular diseases such as congestive heart failure (CHF) (Centers for Disease Control and Prevention, 2015). Many factors have increased the incidence of chronic disease including social determinants of health (underlying socioeconomic, cultural, political and environmental determinants) in addition to individual risk factors (tobacco use, lack of physical exercise, unhealthy diet, age, and genetics) (World Health Organization, 2005). Social determinants of health impact access and research has found that poorer access to healthcare has contributed to the increase in chronic disease (Brooks et al., 2010). Telehealth interventions can potentially improve healthcare access and health outcomes in the United States while saving time and economic resources. Telehealth provides the option to deliver health services to patients remotely through telecommunication technologies such as web-based video chat capabilities, telephone consultations, and at-home monitoring (Botsis and Hartvigsen, 2008). Since people do not have to travel as far or as often to see a doctor, telehealth has the potential toincrease access to care.

Access to healthcare remains a significant challenge in the United States, especially in rural communities that have older, poorer, and sicker residents compared to their urban counterparts (Health Resources and Services Administration, 2015). Unfortunately, rural areas also have fewer primary care physicians and significant physician mobility (McGrail et al., 2017). Telehealth has been identified as a potential strategy to increase healthcare access in communities that are geographically isolated (Rosenblatt & Hart, 2000). Telehealth interventions can potentially help people manage their chronic diseases and improve health outcomes and rural health disparities. Once the effectiveness of a new medical treatment or technology has been established, it is often

necessary to demonstrate the cost-effectiveness in order to increase adoption, especially when start-up costs are high. One potential barrier to the adoption of telehealth interventions is the uncertainty about start-up costs and the cost-effectiveness of these interventions. Research assessing the cost effectiveness is critical for informing these decisions.

While there has been research to determine cost-effectiveness of telehealth, no study to-date has shown conclusive evidence that these interventions are cost-effective in the United States. This analysis compiles and reviews the existing literature on the cost-effectiveness of telehealth interventions for chronic cardiovascular diseases and COPD.

II. Methodology

A literature search was undertaken to identify studies that assessed the cost-effectiveness of telehealth interventions for chronic cardiovascular diseases and chronic obstructive pulmonary disease (COPD) using the following two databases: PubMed and Scopus. Utilizing PubMed's medical subheadings (MeSH) resource by searching the subheadings *telemedicine*[1] and *cost benefit analysis*[2] led to the identification of 753 articles. All 753 results were then transferred to EndNote where abstracts were reviewed to determine if the study met the inclusion criteria for this review. These criteria included studies published in English, published between January 1, 2000-August 31, 2017, included a cost-effectiveness evaluation, and looked at the impact on patients with COPD and chronic cardiovascular disease, such as congestive heart failure, myocardial infarctions, and

[1] Telemedicine is the MeSH entry term for Mobile Health, Health, Mobile, mHealth, Telehealth, and eHealth.
[2] Cost benefit analysis is the MeSH enry term for: Analyses, Cost-Benefit; Analysis, Cost-Benefit; Cost-Benefit Analyses; Cost Benefit Analysis; Analyses, Cost Benefit; Analysis, Cost Benefit; Cost Benefit Analyses; Cost Effectiveness; Effectiveness, Cost; Cost-Benefit Data; Cost Benefit Data; Data, Cost-Benefit; Cost-Utility Analysis; Analyses, Cost-Utility; Analysis, Cost-Utility; Cost Utility Analysis; Cost-Utility Analyses; Economic Evaluation; Economic Evaluations; Evaluation, Economic; Evaluations, Economic; Marginal Analysis; Analyses, Marginal; Analysis, Marginal; Marginal Analyses; Cost Benefit; Costs and Benefits; Benefits and Costs; Cost-Effectiveness Analysis; Analysis, Cost-Effectiveness; and Cost Effectiveness Analysis.

coronary heart disease. Exclusion criteria included studies that focused on diseases other than chronic cardiac conditions and COPD, studies not written in English, studies that did not conduct a physical telehealth intervention, and studies that did not include a cost effectiveness analysis. This review process led to the identification of 27 articles that met the inclusion criteria – 17 of these articles were research studies, 9 were literature reviews, and 1 was a meta-analysis. Of the 17 studies, 1 was conducted in Australia, 1 in Belgium, 2 in Canada, 1 in Denmark, 1 in Germany, 1 in the Netherlands, 1 in Spain, 2 in Taiwan, 3 in the United Kingdom, and 3 in the United States.[3]

III. Literature Review

i) Individual Chronic Cardiovacular Disease Studies

Five studies performed outside the United States found that telehealth interventions were comparable or more cost-effective than usual care for patients with chronic cardiovascular diseases. For example, Ho et al. (2014) and Chen et al. (2013), researchers affiliated with their Telehealth Center, conducted two studies at the National Taiwan University Health Center during different time periods. The purpose of their studies was to assess the clinical outcomes and cost-effectiveness of a telehealth program for patients with chronic cardiovascular diseases, including 1) coronary heart disease with or without percutaneous coronary intervention, 2) myocardial infarction, 3) congestive heart failure, 4) arrhythmia, including bradyarrhythmia, tachyarrhythmia, or ventricular arrhythmia with an implantable cardiac defibrillator implant, 5) diabetes mellitus, 6) syncope, 7) =2 CAD risk factors with angina, and 8) other surgical or congenital heart conditions (Chen et al., 2014).

[3] One study, Henderson et al., examines the cost-effectiveness of telemedicine for patients with chronic conditions including COPD and CHF

Ho et al. (2014) retrospectively analyzed 575 patients who had joined a telehealth program and compared them with 1178 patients undergoing usual care matched for sex, age, and Charlson comorbidity index.[4] Their study was conducted between December 2009 and April 2013. They matched patients with chronic cardiovascular disease that entered the telehealth program with patients that received usual care at their cardiovascular center using age, gender, and the Charlson comorbidity index. The telehealth program transmitted biometric data from the patients' homes, and patients had access to decision-making support without seeing a doctor in person. This program also included daily phone interviews. The researchers collected data on hospitalization, emergency department (ED) visits, and medical costs from the hospital's database and the costs were adjusted to the follow-up months. The cost-effectiveness of telehealth care over usual care was assessed by using a bootstrap analysis method.[5] The data is summarized in the following table:

Table 3.1. Monthly Cost Data of the Telehealth Program Conducted in Taiwan by Category

	Control Group mean (SD)	Telehealth Group mean (SD)
ED visits	$37.30 (126.20)	$20.90 (66.60)
Hospitalizations	$878.20 (2,697.20)	$37.30 (126.20)
All Medical Costs	$1,163.60 (3,036.60)	$587.60 (1,497.80)

Even though the intervention cost an additional $224.80 per month, total monthly costs ($812.40) in the Telehealth Group were still less than all medical costs in the control group, as seen in the above table (Ho et al., 2014). Chen et al. (2013) conducted a quasi-experimental study between November 2009 and April 2010 recruiting a total of 141 patients who received telehealth services at the same hospital in the same program as Ho et al. (2014). They collected data on hospital visits

[4]This index contains 19 categories of comorbidity and predicts the ten-year mortality for a patient who may have a range of co-morbid conditions. Each condition is assigned a score of either 1, 2, 3, or 4 depending on the risk of dying associated with this condition. This helps to control for the impact of comorbidities on study outcomes.

[5]A test or metric that relies on random sampling with replacement. Bootstrapping allows assigning measures of accuracy (defined in terms of bias, variance, confidence intervals, prediction error or some other such measure) to sample estimates.

and hospital expenditures for six months before and after the opening of the hospital's Telehealth Center to assess clinical outcomes and cost-effectiveness of the program for patients with cardiovascular disease. The study found that the intervention significantly reduced the monthly all cause admission rate and the duration of all cause hospital stays. They also found that the intervention significantly reduced the monthly inpatient costs and total cost per month (Chen et al., 2013). From these studies, one can infer that in Taiwan's integrated health care system, this telehealth intervention was more cost-effective than usual care.

Whittaker and Wade's study (2010) in the United Kingdom, a nation that has a government run healthcare system, also found cost savings for a home telehealth-based cardiac rehabilitation program. Their randomized controlled trial (RCT) included 120 participants; 60 participants each randomly assigned to the telehealth program or to usual care. The telehealth program included a cell phone with daily text messaging, a Wellness Diary, and access to a Wellness web portal. Usual care consisted of the standard 6-week hospital-based outpatient rehabilitation program. On average, the telehealth program saved providers £212 ($307.29)[6] and saved patients £320 ($463.84) in travel costs. Both groups showed significant improvements in both clinical parameters and health-related quality of life measures. There were no significant differences in health outomes between the two groups during the study period. (Whittaker and Wade, 2010). Another RCT conducted in Belgium that also studied the effect of home telehealth-based cardiac rehabilitation, found cost-savings for the provider, while also providing patients with better health outcomes (Frederix et al., 2015). In this study, Frederix et al. (2015) randomized 140 patients into two groups: a 24 week long tele-rehabilitation program plus usual care and usual care only. They

[6] All exchange rates to US dollars used are of January 1st of the year the study was conducted.

found that the intervention group had significant cost savings and fewer lost days to cardiovascular rehospitalizations.

Another study conducted in the United Kingdom by Henderson et al. (2014) recruited 965 participants within a cluster RCT of 3230 patients to determine incremental cost per QALY (quality-adjusted life year) gained for patients with CHF, COPD, and/or diabetes. QALY is a generic measure of disease burden, including both the quality and the quantity of life lived. It is used in economic evaluation studies to assess the value of the money spent on medical interventions and is calculated by multiplying the utility score of being in a certain health state by the time that the patient experienced that state. Study participants completed a questionnaire that examined telehealth acceptability, effectiveness, and cost effectiveness. In conjunction, hospital data was collected to determine cost-effectiveness. The probability of telehealth being cost effective was 11% at a willingness to pay threshold of £30000 ($48,778.37) per QALY gained. The probability exceeded 50% only if willingness to pay values exceeded £90,000 ($146,335.11). Henderson et al. (2014) concluded that telehealth interventions have a low probability of being cost-effective.

Boyne et al. (2013) also conducted an RCT to determine the cost-effectiveness of telemonitoring of patients with CHF in the Netherlands. A total of 382 patients in 3 different hospitals were randomized to either usual care or telemonitoring and followed for one year. Hospital-related and home costs are estimated based on resource use multiplied by the appropriate unit prices. Information was gathered from the participants through three monthly cost diaries and questionnaires. There were no significant differences in annual costs per patient between groups.

Boyne et al. (2013) found that health-related quality of life showed slight improvement for the telemonotoring group over usual care, but it was not significant. The researchers also found that

at a threshold of €50,000 ($64,795) for cost of care, the probability of telemonitoring being cost-effective was 48%. The cost effectiveness analysis shows a high level of decision uncertainty that can probably be explained by the variability between the participating institutions.

Three studies published between 2001-2008 assess the cost-effectiveness of telehealth interventions for the treatment of chronic cardiac diseases in the United States. Two of these studies were conducted within the Department of Veterans Affairs Health System. In particular, Darkins et al. (2008) followed patients participating in the Coordinated Care/Home Telehealth (CCHT) program between July 2003 and December 2007. This program systematically implements health informatics, home telehealth, and disease management technologies with the purpose of helping patients live independently at home. CCHT provided services to patients with diabetes mellitus (DM), congestive heart failure (CHF), hypertension (HTN), post-traumatic stress disorder (PTSD), chronic obstructive pulmonary disease (COPD), and depression. They found that CCHT had 25% fewer in-patient days of care and a 19% reduction in the number of hospital admissions, six months after enrollment into the program compared to the six months before enrollment. The patients enrolled in CCHT reported a mean satisfaction score rating of 86%, though the study did not report a satisfaction score rating for patients receiving usual care. Noel et al. (2004) conducted a study in the VA Connecticut Healthcare System (VACT) to determine whether home telehealth, when integrated with the health facility's electronic medical record system, reduces healthcare costs and improves quality of life outcomes relative to usual home healthcare services for elderly high resource users with complex heart failure, chronic lung disease, and/or diabetes mellitus by randomizing 104 patients to the telehealth program or usual care. The researchers found that compared to the control group, the intervention significantly decreased at six months the number of days of inpatient hospitalization ($p < 0.0001$), emergency room visits

($p < 0.023$), and A1c levels ($p < 0.001$). The third study, conducted by Jerant et al. (2001), compared three hospital discharge care models for reducing CHF-related readmission charges: (a) home telecare delivered via a 2-way video-conference device with an integrated electronic stethoscope; (b) nurse telephone calls; and (c) usual outpatient care in a hospital in Southern California. This was a small randomized control trial with 37 participants. After a year, mean CHF-related readmission charges were 86% lower in the telecare group ($5850, SD $21,094) and 84% lower in the telephone group ($7320, SD $24,440) than in the usual care group ($44,479, SD $121,214). However, the difference between the telecare group and the nurse telephone group was not statistically significant.

Table 3.2. Telehealth Studies for Patients with Chronic Cardiovascular Diseases

First Author	Year	Country	Type of Intervention	Number of Participants	QALYs Used	Cost-Effective
Boyne, J. J.	2013	Netherlands	Telemonitoring	382	Yes	No difference
Chen, Y.	2013	Taiwan	Telemonitoring	141	No	Yes
Cui, Y.	2013	Canada	Nurse call line	179	Yes	Yes
Darkins, A.	2008	United States	Telemonitoring	17025[7]	No	Yes
Frederix	2016	Belgium	Telemonitoring	140	Yes	Yes
Henderson, C.	2013	United Kingdom	Telemonitoring	965	Yes	No difference
Ho, Y. L.	2014	Taiwan	Telemonitoring	575	No	Yes
Jerant, A. F.	2001	United States	Telemedicine and Nurse Call line	37	No	Yes
Noel, H. C.	2004	United States	Telemonitoring	104	No	Yes
Sohn, S.	2012	Germany	Telemonitoring	1124	No	Yes
Whittaker, F.	2014	United Kingdom	Telerehabilitation	120	No	Yes

ii) Individual Chronic Obstructive Pulmonary Disease (COPD) studies

While the results for the individual studies on cost-effectiveness for chronic cardiac diseases are mostly positive, the results of studies that investigate the cost-effectiveness of telehealth interventions for patients with COPD are far more varied. From 2013 to 2015, three studies

[7] This number includes all Veterans Health Administration (VHA) patients receiving telehealth between July 2003 and December 2007.

published in the United Kingdom assessed the cost-effectiveness of telemonitoring programs for COPD patients after discharge from the hospital compared to usual care. The purpose of the telemonitoring programs was to reduce emergency department visits and hospital admissions. All three studies conclude that the cost of technology outweighed any cost benefit from the program. These studies do report slightly better health outcomes in patients in the telemonitoring programs, but not enough to justify the extra cost (Henderson et al., 2013, McDowell et al., 2015, and Stoddart et al., 2015).

McDowell et al. (2015) identified 110 patients with COPD to study the effect of adding telemonitoring to usual care in Northern Ireland. Their primary outcome was disease specific quality of life over six months. They found that telemonitoring improved quality of life but was not cost-effective. Stoddart et al. (2015) conducted an RCT that studied the cost and cost-effectiveness of telemonitoring versus usual care for patients with COPD. They randomized 256 patients to either telemonitoring or usual care for a 12-month period. The study found the intervention only had a 15% probability of being cost-effective at the usual threshold of £30,000 ($37,984) per QALY. As stated earlier, Henderson et al. (2013) found that a telehealth intervention for patients with COPD, CHF, and diabetes had a low probability of being cost-effective.

Interestingly, a RCT over a period of six months of a telemonitoring program conducted in Australia found significant cost savings of AUD $2,931 (US$2992) (De San Miguel el al., 2013). The study, however, did not find a significant difference in health outcomes (ED visits, hospital admissions, and reduced length of stay) even though the telemonitoring group did have marginally better outcomes. A telemonitoring study that randomized 57 patients with exacerbated COPD after discharge conducted in Denmark also found significant cost savings for COPD patients joining the intervention after hospital discharge versus usual care (Jakobsen et al., 2013).

Two telemonitoring studies, one conducted in Canada and the other in Spain, reported comparable results to the studies conducted in the United Kingdom. Jodar-Sanchez et al. (2014) randomized 45 patients undergoing long-term oxygen therapy for severe COPD into a telehealth group and a usual care group. The telehealth group used monitoring devices at home to send in vital signs. When a patient triggered an alarm, medical staff triaged the patient and decided on next steps. Paré et al. (2006) conducted a quasi-experimental study comparing the costs and effects of 19 patients in a telecare program to a comparable group of 10 patients receiving usual care. Both studies concluded the cost of technology was too expensive to provide significant cost savings (Jodar-Sanchez et al., 2014, and Paré et al., 2006).

Table 3.3. Telehealth Studies for Patients with COPD

First Author	Year	Country	Type of Intervention	Number of Participants	QALYs Used	Cost-Effective
De San Miguel, K.	2013	Australia	Telemonitoring	102	No	Yes
Henderson, C.	2013	United Kingdom	Telemonitoring	965	Yes	No
Jakobsen, A.	2013	Denmark	Telemonitoring	57	No	Yes
Jodar-Sanchez, F.	2014	Spain	Telemonitoring	45	Yes	No
McDowell, J. E.	2015	United Kingdom	Telemonitoring	100	No	No
Paré, G.	2006	Canada	Nurse Call Line	29	No	No
Stoddart, A.	2015	United Kingdom	Telemonitoring	256	Yes	No

iii) Summary of previous literature reviews

Previously published reviews also show variation in the cost-effectiveness of telehealth interventions for people with chronic cardiac diseases or COPD. There is considerable overlap in the studies included in the reviews that fit the selection criteria. Udsen et al. (2014) conducted a literature review of the costs and cost-effectiveness of telehealth for patients with COPD. This review is the most in depth study and its findings are illustrative of those found in other literature reviews. They assess six studies (three from North America and three from Europe) using the

Consensus Health Economic Criteria list (CHEC list) to determine the quality of the economic evidence presented in each paper. This methodology was created through the Delphi method[8] with 23 international experts. Using this method of economic evaluation in systematic reviews should make them more transparent, informative, and comparable (Evers et al., 2005). All studies report the use of home monitoring devices that measure and transmit different physical indicators to nurses who provide personalized feedback to patients during weekdays. In total, the six studies include 559 COPD patients of whom 281 were randomized to the telehealth intervention. While all six studies report a lower average cost per patient with telehealth plus usual care compared with usual care alone, the authors found the quality of the economic evidence to be either mostly poor (5 studies) or moderate (1 study), with CHEC list scores ranging from 21-68%. To provide some perspective, within the CHEC list criteria, a score of greater than 75% is considered high quality, between 50% and 75% is considered moderate quality, and less than 50% is considered poor quality. These authors also recommend that healthcare decision-makers use caution before implementing large scale telemedicine programs due to the lack of strong evidence in favor of clinical cost-effectiveness.

Unfortunately, this is the only published review study that focuses exclusively on COPD patients. The remaining systematic reviews on telemedicine interventions for COPD patients combine studies on a variety of chronic conditions that focus on various outcomes including intervention effectiveness and cost-effectiveness (Barlow et al., 2007, Botsis and Hartvigsen, 2008, Ekeland et al., 2010, Elbert et al., 2014, and Mistry et al., 2014). A possible reason for this is the paucity of studies conducted on telemedicine interventions for patients with COPD. Barlow et al. (2007) only found 3 studies on this topic, Botsis and Hartvigsen (2008) found 5 studies,

[8]A forecasting process framework based on the results of multiple rounds of questionnaires sent to a panel of experts.

Ekeland et al. (2010) found 1 study, and Elbert et al. (2014) found 4 studies. These literature reviews come to similar conclusions about the lack of strong evidence showing the cost-effectiveness of telehealth interventions as Udsen et al. (2014).

Unlike COPD, there are more reviews of telehealth interventions that focus on heart failure patients. Grustam et al. (2014), another group of European researchers, concluded that studies were inconclusive with regard to the cost-effectiveness of telehealth interventions for chronic heart failure (CHF) patients. They selected 32 studies for data extraction and a critical appraisal of the economic evaluation. Not all studies selected were used in their analysis because they do not include their own cost effectiveness analysis. Most studies did not present a comparison of both costs and effects between telehealth intervention and usual care. In addition, many did not include telehealth investment costs. The few studies that assessed cost-effectiveness comprehensively showed that telehealth interventions were cost saving with slight improvement in effectiveness, or comparably effective with similar cost to usual care. Jerant and Nesbitt (2005), in another review, examined the evidence of cost effectiveness of telehealth interventions for patients with heart failure. They found 5 prior systematic reviews on the effectiveness/cost-effectiveness of telehealth interventions and 33 RCTs. Both Grustam et al. (2014) and Jerant and Nesbitt (2005) excluded most of the articles chosen because they did not include enough information to conduct a cost-effectiveness analysis and concluded that there was a lack of necessary data to prove or disprove the cost effectiveness of telehealth interventions for patients with heart failure.

In 2013, the United Kingdom's National Health Service (NHS) conducted a technology assessment of telemonitoring programs after recent discharge in heart failure patients (Pandor et al., 2013). Their literature search identified 3,060 articles. Through their inclusion criteria, 6 RCTs were added to the 15 trials identified from the previous systematic reviews to be included in their

systematic review and network meta-analyses[9]. They found telemonitoring during office hours was the most cost-effective strategy with an estimated incremental cost-effectiveness ratio (ICER) of £11,873 ($19,305) per quality-adjusted life-year (QALY) compared with usual care, whereas human telephone support had an ICER of £228,035 ($37,0773) per QALY compared with telemonitoring during office hours. They did conclude that their findings were based on less than optimal data and that further research is needed (Pandor et al., 2013). Ten years earlier, Louis et al. (2003), another group of British researchers, reviewed 5 studies that assessed the cost-effectiveness for heart failure patients and also concluded that more research is needed. Thus, similar to the literature review of COPD, these researchers could not conclude that telehealth interventions for CHF patients were cost effective.

Table 3.4. Previously Published Reviews

First Author	Year	Study Description	Cost-Effective
Barlow, J.	2007	Review of studies of home telecare for patients with chronic conditions	Unable to determine
Botsis, T.	2008	Review of studies of home telecare for patients with chronic conditions	Users felt telecare led to cost reduction
Ekeland, A. G.	2010	Review of reviews of all telemedicine interventions	Not enough information to conclude the cost-effectiveness of telemedicine interventions
Elbert, N. J.	2014	Review of reviews and meta-analyses of telehealth interventions for patients with somatic diseases	Attention should be given to the development and evaluation of strategies to implement effective/cost-effective eHealth initiatives in daily practice, rather than to further strengthen current evidence
Grustam, A. S.	2014	Cost-effectiveness of telehealth interventions for chronic heart failure patients	Without full economic analyses the cost-effectiveness of telehealth interventions in chronic heart failure remains unknown
Jerant, A. F.	2005	Cost-effectiveness of heart failure disease management incorporating telehealth	Cost-effectiveness of these programs is unproven
Louis, A. A.	2003	Review of telemonitoring for the management of heart failure	More study is needed before conclusions of cost-effectiveness can be determined
Mistry, H.	2014	Critical appraisal of published systematic reviews assessing the cost-effectiveness of telemedicine studies including COPD and CHF	Conclusions cannot be drawn on the cost-effectiveness of telemedicine applications based on the methodological flaws in the economic analysis of the studies included in the reviews

[9] Network meta-analysis, in the context of a systematic review, is a meta-analysis in which multiple treatments (that is, three or more) are being compared using both direct comparisons of interventions within randomized controlled trials and indirect comparisons across trials based on a common comparator (Li et al., 2011).

Pandor, A.	2013	Systematic review and meta-analysis of telemonitoring after recent discharge in patients with heart failure	Despite wide variation in usual care and remote monitoring strategies, cost-effectiveness analyses suggest that telemonitoring during office hours was an optimal strategy
Udsen, F. W.	2014	Systematic review of the cost and cost-effectiveness of telehealth for patients suffering from chronic obstructive pulmonary disease	Quality of the economic evidence was poor, no definite conclusions can be made

V. Limitations and Strengths of the Literature

The literature on cost-effectiveness of telehealth interventions has many limitations. First, there is a limited amount of research conducted on the topic for patients with chronic cardiovascular conditions and COPD. These included many studies with small sample sizes. Also, all the most recent research was done in Europe and Asia. It is difficult to draw conclusions from different countries because they have varying health systems. Many of the international studies were conducted in countries with universal healthcare coverage. The most current American study was published in 2008. All three American studies were done in the Veterans Administration Health System, which is not reflective of the rest of the United States' healthcare system where most people receive their care.

The 9 literature reviews discussed conclude that studies with a stronger economic analysis component need to be conducted. These reviews looked at studies done in Australia, Europe, North America, and Taiwan. One reason for this limitation may be due to the United States' government restriction on using the measure of "dollars per quality adjusted life year (QALY) as a threshold to establish what type of health care is cost effective or recommended" (The Patient Protection and Affordable Care Act, 2010) for the Medicare program. The Patient-Centered Outcomes Research Institute (PCORI) is therefore limited in the types of analyses it is able to support.

Another limitation of the research is the variability in the cost-effectiveness of the same intervention depending on contextual factors such as study population demographics, local and

regional hospital environment, availability of social supports, and others. Providers need to be aware of the research to be sure it can be replicated in their setting.

Another challenge to determining cost-effectiveness of telehealth programs is that many studies include multiple diseases and people with multiple co-morbidities. The likelihood of a person having co-morbidites increases with age, so it is difficult to determine the cost-effectiveness of a program for a singular chronic condition. Multiple studies reviewed included people with CHF, COPD, and/or diabetes to circumvent this issue. Also, these studies included multiple types of telehealth programs including telemonitoring and telecare. The technology costs for different types of telehealth vary wildly which makes it challenging to draw conclusions about the cost-effectiveness of telehealth programs as a whole. Lastly, it is difficult to generalize cost-effectiveness when countries have different thresholds for assessing cost-effectiveness.

One of the strengths of this literature is the range of studies and study protocols that have been performed and that might serve as pilots for future studies. Also, the research included in this review studied different interventions in different countries. This too could be a basis for future research.

IV. Discussion

The current paucity of cost-effectiveness studies on telehealth, particularly in the United States, is an important barrier that may be slowing the implementation of these interventions and programs. As the population of the United States ages, the need for the improved management of chronic diseases such as COPD and CHF will continue to increase . Providing better care at lower costs is a critical goal moving forward. Many of the studies to-date looking at the cost-effectiveness of telehealth are limited by small sample sizes. There is a possibility that bringing telehealth

programs to scale can result in cost savings. In addition, the rapidly changing technology and costs of technology impact their cost-effectiveness and the generalizability of previous studies.

If the United States' Congress amends the restriction on funding research using QALYs, PCORI could broaden its support for cost-effectiveness studies, including those evaluating telehealth interventions. Cost is a major barrier to the adoption of telehealth services in the United States (Lin et al., 2018). If more studies are able to demonstrate cost-effectiveness, this may lead to greater adoption of these interventions.

Due to the limitations of the research, it is difficult to conclude if telehealth is a promising approach. Studies conducted on the cost-effectiveness of telehealth for patients with chronic cardiovascular diseases showed promising results, yet the studies conducted for patients with COPD did not conclusively show cost-effectiveness. Previous literature reviews also could not definitively conclude that telehealth was cost-effective. These reviews all call for further research before any conclusions can be made.

VI. Conclusions

In spite of the promise of telehealth interventions and programs to improve care and reduce costs for patients with chronic cardiovascular disease and COPD, based on currently available research, it is difficult to conclude if they are cost-effective. Due to the lack of U.S. studies, small sample sizes, and inconclusive results of previous studies, more research is needed. Innovations in health information technology will continue to increase the opportunities for telehealth interventions as well as the cost-benefit tradeoffs. Thus, there is critical need for research that evaluates the cost-effectiveness of these new approaches. As the burden of chronic diseases continues to grow in an aging U.S. population, leveraging technology to improve access to care will remain a critical strategy, especially for disadvantaged and geographically isolated

populations. Ensuring that these new technologies are both effective and cost-effective is an important research priority.

VII. References

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